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# The Effect of Treating Acrylic Resin Denture Base Material with Processed Mushroom Microparticle Solution on the Engineering and Biomaterial Properties

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## Abstract

**Background**: Different types of material have been used for many years as a denture base material, but heat-cure acrylic denture base material is still the most popular for making removable prostheses due to its many advantages, including good strength, stability, aesthetic low water sorption; however, this material also has many drawbacks, including mechanical and hygienic weaknesses, as it is porous and can trap food and microorganisms. The aim of this study was to measure the effect on biomaterial properties of adding a processed mushroom microparticle (PMM) solution to methyl methacrylate (MMA), the monomer of polymethyl methacrylate (PMMA), including transverse and impact strength, water sorption, and its effect on specific types of microorganisms.

**Methods and Results**: The edible mushroom type *Agaricus bisporus* (white button mushroom) was used as a microparticle solution to be mixed with MMA to test its antibacterial, antifungal effects, and its effect on the PMMA mechanical properties. According to the test type, 120 samples were prepared; 10 samples were used for each test and each group.

Bacterial strains (*Staphylococcus aureus* and *Klebsiella* spp.) and *Candida albicans* were used in this study to investigate antibacterial and antifungal activity. A scanning electron microscope (SEM) was used to confirm the size of processed micro particles. Fourier transform infrared spectroscopy (FTIR) was used to identify organic, inorganic, and polymeric materials.

PMM was tested against *Staphylococcus aureus*, *Klebsiella* spp., and *Candida albicans*, and the results showed no effect on the bacteria; it inhibited only *Candida albicans*, with an inhibition zone diameter of 10mm. The results for MMA alone showed no effect on *Staphylococcus aureus* and *Candida albicans*, but it did affect only *Klebsiella* spp. However, after mixing MMA with 10% PMM, the natural extract showed a synergistic effect against *Staphylococcus aureus*, *Klebsiella* spp., and *Candida albicans*, with inhibition zones of 7 mm, 8 mm, and 9 mm, respectively. The inhibition zone diameters of acrylic discs containing PMM were 19 mm, 21 mm, and 16 mm for *Staphylococcus aureus*, *Klebsiella* spp., and *Candida albicans,* respectively, whereas the MMA group showed no effect. There was a highly significant increase in transverse and impact strengths for the processed group, compared to the MMA group, and a highly significant reduction in water sorption for the processed group, compared to the MMA group.

**Conclusion**: The addition of PMM to the MMA monomer and subsequent mixing with PMMA powder yielded noticeable results from both mechanical and biological perspectives.(**International Journal of Biomedicine. 2026;16(2):248-252.**)

**Keywords**: acrylic denture material • antifungal agents • mechanical phenomena

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## Abbreviations

**AFM**, atomic force microscopy; **FTIR**, Fourier transform infrared spectroscopy; **PMMA**, polymethyl methacrylate; **PMM**, processed mushroom microparticle; **SEM**, scanning electron microscopy.

# Introduction

Different types of material have been used for many years as a denture base material, but heat-cure acrylic denture base material is still the most popular for making removable prostheses due to its many advantages, including good strength, stability, aesthetic low water sorption; however, this material also has many drawbacks, including mechanical and hygienic weaknesses, as it is porous and can trap food and microorganisms.[1] Therefore, many attempts have been made over the years to improve the mechanical properties of polymethyl methacrylate (PMMA). These methods included adding fiber and graft copolymerization, and using natural extracts, all considered promising approaches to improve the material's properties.[2-4] Also, these additions or alterations to PMMA to improve its mechanical properties need to be safe and maintain biocompatibility.[5]

Edible mushrooms show no harmful or toxic effects.[6] Mushrooms contain amino acids, protein, fiber, and erythritol, a widely recognized, non-cariogenic sweetener that does not contribute to tooth decay and, unlike sugar, is not metabolized by oral cariogenic bacteria such as *Streptococcus mutans* and *Streptococcus sobrinus*.[7] Furthermore, studies indicate that erythritol actively inhibits the growth, adherence, and biofilm formation of *Streptococcus mutans* and *Streptococcus sobrinus*.

Based on previous studies that used edible mushroom type *Lentinula edodes* (shiitake mushroom), it was found to have an antiplaque effect as it reduces *Streptococcus mutans* growth through inhibiting DNA production, in addition to the same effect on streptococcal species.[8,9,10]

The aim of this study was to measure the effect on biomaterial properties of adding a processed mushroom microparticle (PMM) solution to methyl methacrylate (MMA), the monomer of PMMA, including transverse and impact strength, water sorption, and its effect on specific types of microorganisms.

# Methods

In this study, the edible mushroom type *Agaricus bisporus* (white button mushroom) was used as a microparticle solution to be mixed with MMA to test its antibacterial, antifungal effects, and its effect on the PMMA mechanical properties.

In the processed group, MMA was mixed with 10% PMM and heat-cure acrylic powder of PMMA (Pyrax, India), according to the manufacturer's instructions. The 10% PMM concentration was selected based on a pilot study in which 3 PMM concentrations (5%, 10%, and 15%) were added to MMA to assess their effects on *Staphylococcus aureus, Klebsiella* spp., and *Candida albicans*. The ingredients were mixed by slowly adding PMM to MMA to ensure complete coverage at a temperature below 50°C, thereby preventing structural damage.

### Preparation of Processed Mushroom Microparticle Solution

The mushroom powder was prepared by drying mushrooms for 3 weeks, then smashing them with a silver-crest grinding degree of 30-300 at a rotating speed of 28,000 r/min for 5 min per round, 3 times. After each smashing process, the powder was sifted through a 38-micrometer-pore sieve. The final powder was converted into a microparticle solution by a physical method (top-down): 2g of mushroom powder was added to 100ml of distilled water in a magnetic stirrer at 50°C for 10 hours, then the solution was filtered 4 times using filter paper. Next, the solution was precipitated at 50 µL/min using a stirrer at 60°C to produce tin films for testing[11] (Figure 1). A scanning electron microscope (SEM) was used to confirm the size of processed micro particles. The particle size was between 1-2 µm, according to the SEM test.

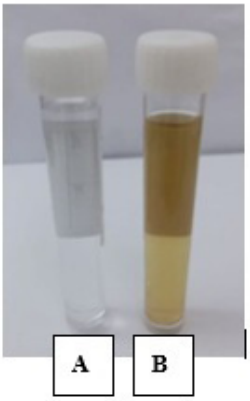


***Fig. 1.*** *A represents distilled water, B represents PMM.*

### Antibacterial Activity

Bacterial strains (*Staphylococcus aureus* and *Klebsiella* spp.) and *Candida albicans* were used in this study to investigate antibacterial and antifungal activity. The cork borer method was used to make the agar well in the plates.[12] Incubation durations for *Staphylococcus aureus* were 18 and 24 hours, while for *Candida albicans*, it was 24-72 hours. Then the inhibition zone was calculated in mm.[13] The bacterial and Candida sources were obtained from Medical City, a teaching hospital in Baghdad. The measurement method was used in an in vitro study and did not involve human subjects or animals.

### Preparation of Samples

According to the test type, 120 samples were prepared; 10 samples were used for each test and each group (Figure 2). The rectangular-shaped samples were prepared for each of the flexural tests with dimensions based on ANSI/ADA No.12; for the impact test, the dimensions of the samples were 60 mm ×12 mm × 3 mm; for the water sorption test circle samples with dimensions 50 mm × 0.5 mm were prepared according to ADA No.12.[14] For water sorption, the measuring method involved the equation (M2-M1 mg/surface area $cm^2$) by immersing the samples in distilled water for one week. Samples were measured with a sensitive electronic balance with precision 0.00001g. The dimensions of the bacterial inhibition zone were 10 mm × 2 mm. Flexural tests were performed on a universal testing machine; impact tests were performed using the Izod impact test.

Fourier transform infrared spectroscopy (FTIR) was used to identify organic, inorganic, and polymeric materials.

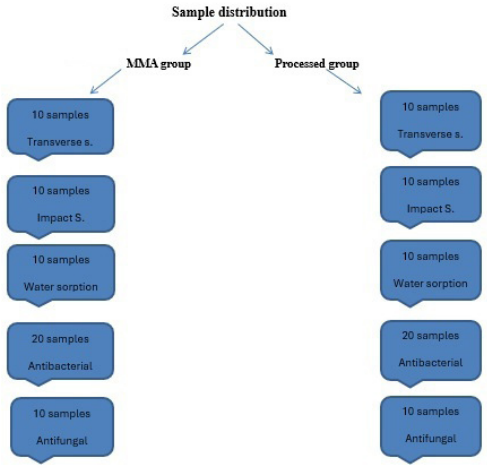


***Fig. 2.*** *Sample numbers and distribution for each test and group.*

Statistical analysis was performed using SPSS version 24.0 (IBM Corp., Armonk, NY). For the descriptive analysis, results are presented as mean (M) ± standard deviation (SD). For normally distributed data, inter-group comparisons were performed using Student's t-test. A probability value of $P < 0.05$ was considered statistically significant.

## Results

The results of scanning electron microscopy (SEM) and atomic force microscopy (AFM) indicated that the PMM particles had reached the microscale, as the material contained fibers that could not be further reduced, and that the particle surfaces were smooth (Figure 3).

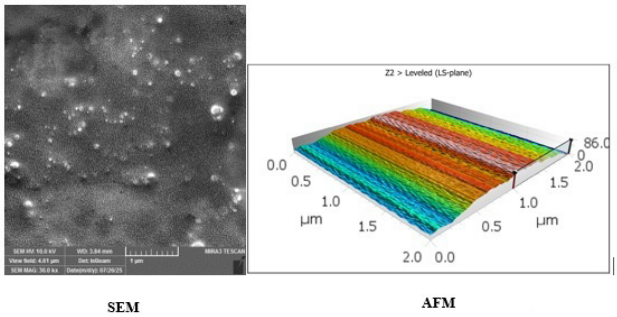


***Fig. 3.*** *The results of SEM and AFM.*

The results of FTIR for both control and processed groups showed that the changes that occurred in the processed group involved a shortage at peak 2924 $cm^{-1}$ and 2854 $cm^{-1}$ that refer to C-H alkane, and this could be explained as the PMM was added in a small amount (10%) as an additive that made the changes in the chemical formula of the new group unremarkable (Figure 4).

PMM was tested against *Staphylococcus aureus*, *Klebsiella* spp., and *Candida albicans*, and the results showed no effect on the bacteria; it inhibited only *Candida albicans*, with an inhibition zone diameter of 10 mm. The results for MMA alone showed no effect on *Staphylococcus aureus* and *Candida albicans*, but it did affect only *Klebsiella* spp. However, after mixing MMA with 10% PMM, the natural extract showed a synergistic effect against *Staphylococcus aureus*, *Klebsiella* spp., and *Candida albicans,* with inhibition zones of 7 mm, 8 mm, and 9 mm, respectively. The inhibition zone diameters of acrylic discs containing PMM were 19mm, 21mm, and 16mm for *Staphylococcus aureus*, *Klebsiella* spp., and *Candida albicans*, respectively, whereas the MMA group showed no effect (Figure 5).

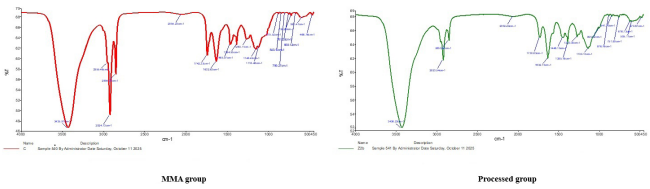


***Fig. 4.*** *FTIR for the MMA and processed groups.*

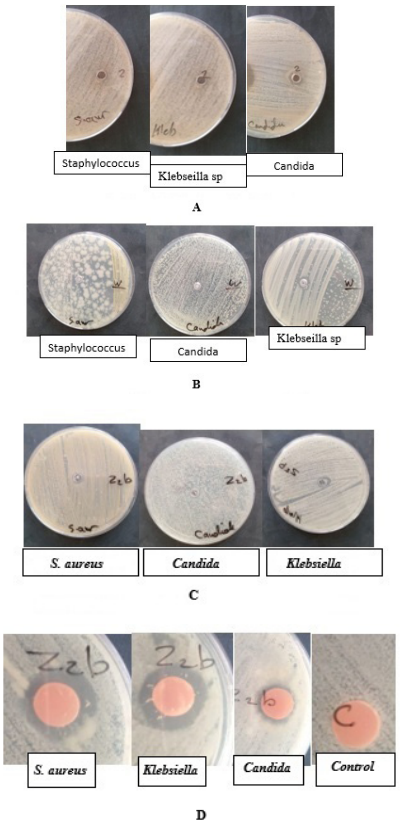


***Figure 5.***

***A****. Effects of PMM on Staphylococcus aureus, Klebsiella spp., and Candida.*

***B****. Effects of MMA on Staphylococcus aureus, Klebsiella spp., and Candida.*

***C****. Effects of PMM and MMA on Staphylococcus aureus, Klebsiella spp., and Candida.*

***D****. Diameter of inhibition zone.*

Statistical analysis showed a highly significant increase in transverse and impact strengths for the processed group, compared to the MMA group (Tables 1 and 2), and a highly

significant reduction in water sorption for the processed group, compared to the MMA group (Table 3).

***Table 1.***

***Descriptive and statistical test of transverse strength (MPa) between groups.***

| | MMA group | Processed group | *P*-value |
|---|---|---|---|
| Minimum | 45.000 | 70.000 | 0.004 |
| Maximum | 70.000 | 93.000 | |
| Mean | 60.800 | 75.100 | |
| ±SD | 9.693 | 9.562 | |

***Table 2.***

***Descriptive and statistical test of impact strength (J/m²) between groups.***

| | MMA group | Processed group | *P*-value |
|---|---|---|---|
| Minimum | 0.400 | 0.400 | 0.002 |
| Maximum | 0.450 | 0.550 | |
| Mean | 0.430 | 0.490 | |
| ±SD | 0.026 | 0.046 | |

***Table 3.***

***Descriptive and statistical test of water sorption (µg/mm³) between groups.***

| | MMA group | Processed group | *P*-value |
|---|---|---|---|
| Minimum | 20 | 20 | 0.026 |
| Maximum | 80 | 40 | |
| Mean | 52 | 30 | |
| ±SD | 8 | 3 | |

# Discussion

A synergistic inhibition effect of MMA with 10% PMM on the growth of *Staphylococcus aureus*, *Klebsiella* spp., and *Candida albicans* was probably due to the homogenous mixing and dissolving process of PMM in MMA.

As for mechanical properties, transverse and impact strength were significantly higher in the processed group than in the MMA group. This is probably due to PMM acting as a filler to fill the spaces left after MMA evaporation and may also be attributed to homogeneous distribution between PMM and MMA. Both PMM and PMMA are considered organic materials.[15] Our study aligns with principles used to improve PMMA's mechanical properties by altering its chemistry or adding fillers.[16,17] The results also coincide with those reported by Fahimeh et al.,[18] who improved some mechanical properties of PMMA by adding nanosilver.

The water sorption is considered an important mechanical property in PMMA as it could affect the quality of denture materials, which are affected by the nature of the water environment, the polymer molecular composition, and the additives present in the mixture. The results of this study for water sorption showed a significantly reduced effect for the processed group, compared to the MMA group. This was probably due to a reduced number of microscopic pores and homogenous mixing between PMM and PMMA.[19-22]

**In conclusion**, the addition of PMM to the MMA monomer and subsequent mixing with PMMA powder yielded noticeable results from both mechanical and biological perspectives.

# Author Contributions

**Zahraa Saad A. Karkosh**: Conceptualization, Investigation, Data analysis/interpretation, Writing – review and editing.
**Omer Abdul Jabbar Abdul Qader**: Data curation, Data analysis, Writing – original draft.
**Abeer A. Yahya**: Investigation, Data curation, Sample preparation.
**Alyaa Saad Abed**: Investigation, Formal analysis, Writing – original draft.
All authors have approved the final article.

# Conflict of Interest

The authors have declared no conflict of interest.

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